

The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform Climate Smart Agriculture interventions

Hammond, James; Fraval, Simon; van Etten, Jacob ; Suchini, Jose Gabriel ; Mercado, Leida ; Pagella, Tim; Frelat, Romain ; Lannerstad, Mats ; Douxchamps, Sabine ; Teufel, Nils ; Valbuena, Diego ; van Wijk, Mark T.

Agricultural Systems

DOI:

[10.1016/j.agsy.2016.05.003](https://doi.org/10.1016/j.agsy.2016.05.003)

Published: 01/02/2017

Peer reviewed version

[Cyswllt i'r cyhoeddiad / Link to publication](#)

Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):

Hammond, J., Fraval, S., van Etten, J., Suchini, J. G., Mercado, L., Pagella, T., Frelat, R., Lannerstad, M., Douxchamps, S., Teufel, N., Valbuena, D., & van Wijk, M. T. (2017). The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform Climate Smart Agriculture interventions: Description and applications in East Africa and Central America. *Agricultural Systems*, 151(February), 225-233.
<https://doi.org/10.1016/j.agsy.2016.05.003>

Hawliau Cyffredinol / General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

1 The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform
2 Climate Smart Agriculture interventions: description and applications in East Africa and Central America
3
4
5 Authors: James Hammond^{ab}, Simon Fraval^c, Jacob van Etten^d, Jose Gabriel Suchini^e, Leida Mercado^e, Tim
6 Pagella^{ab}, Romain Frelat^c, Mats Lannerstad^c, Sabine Douxchamps^c, Nils Teufel^c, Diego Valbuena^{fg} & Mark
7 T. van Wijk^{c*}

8
9 ^a International Centre for Research on Agroforestry (ICRAF), Nairobi, Kenya

10 ^b School of the Environment, Natural Resources and Geography, Bangor University, UK

11 ^c International Livestock Research Institute (ILRI), Livestock Systems and the Environment, Nairobi, Kenya

12 ^d Bioversity International, Turrialba, Costa Rica

13 ^e Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica

14 ^f International Center for Tropical Agriculture (CIAT), PO Box 172, Managua, Nicaragua

15 ^g Wageningen University (WUR), PO Box 430, 6700 AK Wageningen, The Netherlands

16 * Corresponding author. Email: m.vanwijk@cgiar.org

17

Abstract

Achieving climate smart agriculture depends on understanding the links between farming and livelihood practices, other possible adaptation options, and the effects on farm performance, which is conceptualised by farmers as wider than yields. Reliable indicators of farm performance are needed in order to model these links, and to therefore be able to design interventions which meet the differing needs of specific user groups. However, the lack of standardization of performance indicators has led to a wide array of tools and ad-hoc indicators which limit our ability to compare across studies and to draw general conclusions on relationships and trade-offs whereby performance indicators are shaped by farm management and the wider social-environmental context .

RHoMIS is a household survey tool designed to rapidly characterise a series of standardised indicators across the spectrum of agricultural production and market integration, nutrition, food security, poverty and GHG emissions. The survey tool takes 40-60 minutes to administer per household using a digital implementation platform. This is linked to a set of automated analysis procedures that enable immediate cross-site benchmarking and intra-site characterisation. We trialled the survey in two contrasting agro-ecosystems, in Lushoto district of Tanzania (n=151) and in the Trifinio border region of Guatemala, El Salvador and Honduras (n=285). The tool rapidly characterised variability between farming systems at landscape scales in both locations identifying key differences across the population of farm households that would be critical for targeting CSA interventions.

Our results suggest that at both sites the climate smartness of different farm strategies is clearly determined by an interaction between the characteristics of the farm household and the farm strategy. In general strategies that enabled production intensification contributed more towards the goals of climate smart agriculture on smaller farms, whereas increased market orientation was more successful on larger farms. On small farms off-farm income needs to be in place before interventions can be promoted successfully, whereas on the larger farms a choice is made between investing labour in off-farm incomes, or investing that the labour into the farm, resulting in a negative association between off-farm labour and intensification, market orientation and crop diversity on the larger farms, which is in complete opposition to the associations found for the smaller farms. The balance of indicators selected gave an adequate snap shot picture of the two sites, and allowed us to appraise the 'CSA-ness' of different existing farm strategies, within the context of other major development objectives.

Key-words: farm household, smallholder farming, multiple indicators, monitoring

54 **Introduction**

55

56 At present approximately 75% of the world's poor live in rural areas (Livingston et al., 2011), and many of
57 those are in areas where climate change is expected to have a significant detrimental impact on top of current
58 and future agricultural demand and development challenges. Predicted changes in rainfall and temperature
59 patterns will strongly affect agricultural production, with changed crop production and yields; causing
60 increased vulnerability of many rural communities. As much as 22% of the cultivated area under the world's
61 most important crops is projected to experience negative impacts from climate change by 2050, with as much
62 as 56% of the land area in sub-Saharan Africa being impacted (Campbell et al., 2011). The overall aim of
63 CSA is to '*support efforts from the local to global levels for sustainably using agricultural systems to*
64 *achieve food and nutrition security for all people at all times, integrating necessary adaptation and*
65 *capturing potential mitigation*' (Lipper et al., 2014, see also Neufeldt et al., 2013). Climate smart agriculture
66 therefore has three main pillars, to be considered at different spatial and temporal scales (FAO, 2013): 1.
67 achieve food security, 2. adapt and build resilience to climate change and 3. reduce greenhouse gas emissions
68 to mitigate further climate change.

69

70 There is an urgent need to improve the characterisation of agricultural systems at household level to enable
71 more efficient assessment of capacity for adoption of climate smart measures. Capacity to adopt is
72 intrinsically linked with the potential success of those measures, which means assessing trade-offs amongst
73 multiple outcome objectives for adopters. Local drivers and factors need to be identified that might constrain
74 or provide opportunities within a specified agricultural system (Carletto et al., 2015), while on the other hand
75 generalizable standardised characteristics need to be identified that would allow robust comparisons between
76 different systems (Frelat et al., 2016; Van Wijk, 2014). One way to assist the assessment of opportunities at
77 smallholder farm household level for climate smart agriculture (CSA) can be through integration of
78 standardized agricultural, poverty, nutrition and environmental indicators in the quantitative characterization
79 of these households. This will allow us to assess how these performance indicators vary across a farm
80 population, across different sets of farm practices present in the farm population and across different agro-
81 ecological and socio-economic conditions as well as how they may change over time.

82 At present household level characterisation studies are hampered by a variety of problems. A recent analysis
83 of farm household level survey data collected in different agricultural development oriented projects, showed
84 large differences in content between different survey instruments, with lack of standardization of indicators
85 and evidence that only a small amount of the information collected during lengthy surveys could actually be
86 used for cross-site comparisons (Frelat et al., 2015). This lack of standardization in combination with often
87 relatively poor data quality (Tiffen et al., 2003), generally caused by unsuitable survey design (Randall and
88 Coast, 2015) or by biases due to perverse incentives (Sandefur and Glassman, 2015), has led to a lack of
89 quantitative insight beyond the locality of each study regarding the effect of interactions between proposed
90 adaptation options and the wider socio-economic and biophysical environment on household level

performance indicators. For example, we know little on how household food security has been affected by trends in agricultural production in different regions of the world (Carletto et al., 2013) or what the effects of adopting of CSA options are. The lack of integrated survey approaches hampers our knowledge of trade-offs and/or synergies between indicators at farm household level (e.g. Klapwijk et al., 2014), and of how these relationships and trade-offs are shaped by farm management and by social and bio-physical environments (Carletto et al., 2015; de Weerd et al., 2015).

In this paper we describe a new standardised modular survey tool called RHoMIS (Rural Household Multi-Indicator Survey) that tries to overcome the current problems associated with household characterization surveys. The RHoMIS tool is constructed from a set of standardised performance indicators that run across the three pillars of CSA, and aims to allow us to quantitatively analyse the links between agricultural management strategies and farm household performance. RHoMIS is designed to provide rapid characterisations of both farm practices and farm performance in order to enable i) the assessment of the ‘CSA-ness’ of different farm practices and strategies, ii) how the achievement of ‘CSA-ness’ is associated with the achievement of other household development objectives, and iii) to identify which strategies are more effective for which groups of farmers. We applied the RHoMIS tool by carrying out two surveys in contrasting sites, one in Central America and one in East Africa, and evaluated the degree to which various farming strategies contribute towards the objectives of CSA, for different types of farmers.

Methods and Materials

Principles and general design of the RHoMIS tool

The RHoMIS (Rural Household Multiple Indicator Survey) tool consists of a farm household survey that can be conducted on a digital platform using smart phones or tablets using the Open Data Kit (ODK) suite of software installed on Android based mobile phones or tablets (Hartung et al., 2010). Data can be directly uploaded to a web-server, and an associated set of analysis tools programmed in R extract the data and calculate indicators. The tool has been set up in such a way that additional modules of questions and indicators can be incorporated and analysed depending on the local study needs. In the supplementary material the paper version of the survey is included, while the ODK source code is available on request from the corresponding author. In the near future we will make the tools available through a website.

The survey tool was designed according to the following five principles:

- i) the survey has to be *rapid* enough to avoid participants’ fatigue or annoyance, and keeping costs low to allow for larger sample sizes on a limited budget;
- ii) the survey has to be *utilitarian*, in that all questions asked in the survey are being used in pre-defined analyses, in order to minimise superfluous data collection;
- iii) the survey has to be *user-friendly*, so that all participants in the process of collecting and analysing data can perform the tasks with minimum hassle and resistance, and therefore increase

- speed and data quality;
- iv) the survey has to be *flexible*, so that it can be modified easily to suit the local context of the farming systems and farm households where it will be deployed;
- v) the data gathered has to be *reliable*, in that questions should be easy for respondents to understand and the answers should be based on observable criteria or respondents' direct experience rather than abstract scales or abstract concepts.

Household Performance Indicators

The indicators that are captured by the RHoMIS tool were chosen to represent important factors across the agricultural production, nutrition and poverty relationships, while also capturing key indicators of interest related to climate smart agriculture (i.e. greenhouse gas emissions and gender equity). The survey tool was constructed in a modular way, with each module collecting the information needed to be able to calculate the performance indicator of interest. New indicators of interest to the user can therefore be added easily. The indicator set collected in the current version of the Rhomis tool consists of the following elements:

1) *Food availability* is supply-based estimate of the potential amount of food that can be generated through on and off-farm activities by any one household, and is measured in kilo-calories (kCal) per person (male adult equivalent) per day (Frelat et al., 2016; Ritzema et al., submitted; Van Wijk et al., 2014a). The indicator is calculated from on-farm consumption of food crops and livestock products, and from the amount of food (local staple crop) that could be purchased using the cash incomes earned through selling farm produce and through off-farm activities. It ignores farm costs and household expenses, and therefore only gives an indication of whether certain activities lead to enough food being potentially available to feed the family, and the relative importance of these activities compared to each other. It does not quantify actual consumption.

2) The *household dietary diversity score* (HDDS) is calculated according to the number of different food groups consumed over a given reference period, and is a proxy indicator for diet diversity, the improvement of which is associated with a number of key health indicators such as birth weight, child anthropometric status, and improved haemoglobin concentrations. The HDDS score in RHoMIS follows the instructions of Swindale and Bilinsky (2006) in most aspects but departs from the standard advice in terms of reference time period. A 24 hour recall method is recommended, but we instead asked how often foodstuffs from each food group were eaten during a 4 week period in 'the good season' and 'the bad season'; where respondents could answer that they consume foods from each group either 'daily', 'weekly', 'monthly', or 'never/ less than monthly'. Whilst this approach might result in lower accuracy than a 24 hour recall, the required survey intensity is much less in order to capture seasonal variations. The 12 food groups used were standard, but locally appropriate examples were chosen in each location. The indicator results are on a scale of 0 to 12, where 12 is the most diverse diet in which all 12 food groups are eaten on at least a weekly basis. The data

on consumption frequency within the recall period will allow us more complex interpretations in terms of micro-nutrient use, but will not be analysed in this study.

3) The *Household Food Insecurity Access Scale (HFIAS)* indicator estimates the prevalence of food insecurity and is based on the idea that the experience of food insecurity (access to food) causes predictable reactions and responses that can be captured and quantified through a survey and summarized in a scale. There are nine questions that represent a generally increasing level of severity of food insecurity, and nine “frequency-of-occurrence” questions that are asked as a follow-up to each occurrence question to determine how often the condition occurred (Coates et al., 2007). The approach has been applied successfully in numerous studies in developing countries (Coates et al., 2006). We asked respondents about food insecurity during the worst month (‘bad season’) of the previous year, and frequency options were again ‘daily’, ‘weekly’, ‘monthly’, or ‘never/less than monthly’. The indicator is scored on a range of 0 to 27, where a higher number means a household experiences more food insecure.

4) *The Progress out of Poverty Index (PPI)* is a widely used standard indicator of poverty (Desiere et al., 2015). The PPI is a rapid ten-question survey which estimates the likelihood that a household has an expenditure below a given poverty line, where the score ranges between 0 and 100, and a higher score means a household is less likely to be below the poverty line (Grameen Foundation, 2015). The scorecard uses ten simple indicator questions based on observable household characteristics that are correlated with poverty levels using Living Standards Measurement Surveys or similar, detailed surveys. The PPI approach is now available for 55 countries, amongst which are Guatemala and Tanzania.

5) A *gender equity* indicator was included to quantify the role of women in decision-making and household resource management. The inclusion of gender in resilience and vulnerability assessments is a burgeoning topic (Smyth and Sweetman, 2015; Morchain et al., 2015), and achieving gender equity is an aim of many policies in developing countries. The indicator is constructed based on three questions asked for each farm product or income source: who does most of the work, who usually decides when to eat it, and who sells it; where the possible answers are ‘household males’, ‘household females’ and/or ‘children’. The information was aggregated to an overall score by weighing each activity along the importance it has in the *food availability* indicator, resulting in a final score between 0 and 1, where 1 implies that female decides completely what happens with the benefits generated by different on and off farm activities. This indicator therefore does not deal with ownership of resources, but with the agency to decide what to do with the benefits that result from these resources. We constructed a novel indicator in this case, because although alternatives do exist they were too detailed and complex for our purposes (Johnson and Diego-Rosell, 2015). For example, the Women’s Agricultural Empowerment Index requires 60-80 minutes of interview time per household (Alkire et al., 2013), which is longer than our target time for the full questionnaire.

202 6) Farm level estimates of *Greenhouse Gas (GHG) emissions* were calculated using the IPCC Tier 1
203 approach (IPCC 2006). Tier 1 was chosen because it is a recognised method and has low data demands.
204 Although the Tier 2 approach yields a more detailed GHG assessment, the substantially higher data demands
205 can lead to unreliable data when relying on farmer recall. Key determinants of the Tier 1 estimate of
206 emissions for this indicator are number of cattle and other livestock, land use area and type, inputs of mineral
207 fertilizer and the production and use of manure and crop residues. The indicator does not account for carbon
208 sinks, land use change (even if implemented longitudinally), capital infrastructure, nor farm related
209 electricity or fuel use. Farm greenhouse gas emissions are reported in kilograms CO₂-equivalent per farm per
210 year.

211

212 These were the six core indicators that can be quantified with this version of the RHoMIS tool. The
213 information used to calculate these indicators was also used to calculate several other performance
214 indicators: The questions used to calculate the Food Availability indicator were used to quantify 7) *Farm*
215 *Productivity*, measured in total kilo-calories produced per year per hectare; 8) *Farm Produce Value*, which
216 is the calculated total value of everything produced on the farm, using local prices and reported in US dollars
217 per year ; 9) *Off farm income*, also expressed in 2010 equivalent US dollars, as reported by the households.
218 Finally, the GHG emission indicator and the agricultural production component of FA (including sales and
219 consumption) , expressed in kcal per year, were used to calculate 10) *GHG emission intensity*, expressed in
220 in kgCO₂-eq/kCal.

221

222 *Performance Indicators and CSA Outcomes*

223 Performance indicators each link to one of the three pillars of climate smart agriculture: food security,
224 adaptive capacity, and mitigation (FAO, 2013). In this way, the impacts of existing land use options, farm
225 management practices and / or farm strategies on 'climate smartness' can be measured. By assessing
226 household scores on each indicator, a measure of achievement towards CSA goals can be derived. The logic
227 of this process is represented in Figure 1. Within this framework, food security is related to the indicators
228 Food Availability, Farm Productivity, Household Food Insecurity of Access Score and Household Dietary
229 Diversity Score. Adaptive capacity has been shown to be partially dependant on wealth (Delaney et al.,
230 2014) and is therefore related to the PPI, Cash value of produce and also Gender Equity indicators.
231 Mitigation is related to total GHG emissions per farm and GHG emission intensity.

232

233 *Site Selection & Survey Implementation*

234 Surveys were carried out in two contrasting sites: Trifinio border region of El Salvador, Guatemala and
235 Honduras in Central America, and the Lushoto district in Tanzania, East Africa. Agriculture and livelihoods
236 in both sites are vulnerable to climate change. The contrasting nature of the sites aims to demonstrate the
237 wide applicability of the RHoMIS tool. The sites were selected because they are part of a concerted data
238 gathering effort by various ongoing research programs and projects mentioned below. Lushoto is part of the

239 Eastern Arc Mountains of East Africa which is seen as a global hotspot for biodiversity with diverse micro
240 eco-zones within a relatively small area; mixed crop-livestock, quite intensive farming systems in higher
241 elevation and agro-pastoral farming systems in lower elevation. The Usambara Mountains are an important
242 source of water for northeastern Tanzania and the Pangani River is utilized for urban water supply, irrigation
243 and hydropower generation. Deforestation, poor land management and inadequate funds for watershed
244 management pose a threat to the long-term supply of quality water from the Usambaras to downstream
245 communities. The supply of water might be further affected by climate change with rainfall predicted to
246 become more irregularly distributed. The agricultural system in the Trifinio region in Central America is
247 dominated by dry, steep land with sporadic rainfall and little to no irrigation infrastructure, where the major
248 crops are maize and beans. Trifinio is part of the 'dry corridor' of Central America, and during the past few
249 years rains have become more sporadic, leading to drought conditions since 2014.

250

251 In Lushoto, Tanzania, the survey was conducted on a resample of the farm households that were also
252 surveyed in 2012 with the CCAFS research program (<https://ccafs.cgiar.org/>). In the 2012 survey 200 farm
253 households were randomly selected within the 10 by 10km land block containing representative
254 agroecologies in the study region that were chosen through a participatory process involving a wide range of
255 partners and expert opinion (Kristjanson et al., 2012; Förch et al., 2014). Twenty villages within each block,
256 and then 10 households on average within each village were randomly chosen (Kristjanson et al., 2012) for
257 the household survey. In June 2015 150 households were randomly chosen from the 200 sampled in 2012,
258 and they were interviewed in the first two weeks of July using the digital version of the RHoMIS survey tool.
259 In Trifinio the survey was carried out in conjunction with the baseline survey for the USAID-funded Prueba3
260 project, implemented by Bioversity, CATIE and Zamorano in Trifinio to test Crowdsourcing Crop
261 Improvement (van Etten, 2011). Villages were selected by collaborating organizations as candidate villages
262 for a bean variety introduction experiment, and a subset of 285 households was randomly selected for the
263 RHoMIS survey from the full list of households taking part in the project.

264

265 Surveys were trialled with scientific experts in each study region; with scientific and technical staff resident
266 in each study site; with the enumerators who would implement the surveys; and finally with rural households
267 within the intended implementation area of the surveys. Specific changes were made on the phrasing and use
268 of language, on local units of measurement used, on examples of locally available foodstuffs and other
269 products (e.g. types of fertiliser), on the crops, livestock and livestock products commonly produced, routes
270 to market, and common sources of off-farm income. The survey was conducted in Spanish in Trifinio, and in
271 a mixture of English and Kiswahili in Lushoto.

272

273 *Data analysis*

274 Extraction of data and calculation of the indicators was done using scripts programmed in R. To compare
275 values of performance indicators between the sites, and to assess the overall patterns of and co-variances

276 between the indicators in the two farm populations that were sampled correlations between the indicators and
277 significance levels were quantified using Spearman's rank correlation. Comparisons to assess significant
278 differences in indicator results between the two sites were performed with the Wilcoxon rank-sum test given
279 non-normal distributions of the response variables.

280

281 A more detailed analysis to assess the climate smartness of different farming strategies was performed for
282 both sites. We used farm size and livestock ownership as variables to define 'small' (i.e. farm land area
283 smaller than 1 ha, and livestock ownership of less than 1 tlu) and relatively 'large' farms (i.e. farm land area
284 larger than 1ha and livestock ownerships more than 1 tlu) and contrasted these farms in terms of their
285 performance indicators, and in terms of the response of the performance indicators to different farm
286 strategies. We chose to group the farms using land size and livestock numbers following the analyses of
287 Frelat et al. (2016).

288

289 We selected three common farming strategies to appraise in terms of impact upon climate smartness:
290 Intensification, Diversification and Market Orientation. We selected those three because they have been
291 discussed in literature as being of potential benefit to the goals of Climate Smart Agriculture (Campbell et
292 al., 2014). Intensification was measured in terms of quantity of nitrogenous fertiliser per ha applied to the
293 crops by the farm household, crop diversification was measured by the number of crop species grown by a
294 household, and market orientation was calculated by using the ratio of agricultural production sold relative to
295 the total agricultural production (both expressed in kcal terms). Again we used simple thresholds based on
296 the median score for each farm strategy in each site, so that households could be divided into two groups –
297 those who score higher than average on that practice and those who score lower than average, for example
298 high crop diversity and low crop diversity.

299

300 **Results**

301

302 *Implementation of the survey*

303 Across both sites, the running time for the survey was 40-60 minutes per household (Table 1). Gathering data
304 for the food availability indicator took the longest, between 15 to 35 minutes, as it is based on the whole of
305 agricultural production, sales and off farm income. The dietary diversity indicator took the second longest to
306 complete, at around 10 minutes per household, due to the complexity of explaining the different food types,
307 and introducing the concepts of the 'good season and 'bad season'. All other indicators only took less than 5
308 minutes each (Table 2). The indicators were calculated successfully for most households, we were only
309 unable to calculate less than 1% of all potential indicator data points due to lack of adequate responses.
310 The interviewers were asked to rate the 'easiness' of gathering the data at the end of each module, whilst
311 undertaking the surveys. Ease related to both the ease of asking and phrasing questions, and the ease of
312 extracting the right type of response from the informant. All modules were rated as 'easy' between 50-60%

313 of the time, and rated as medium approximately 30% of the time, except for off-farm incomes, which was
314 rated 'medium' more often than it was rated 'easy'. The Progress out of Poverty Indicator was rated as
315 difficult only 5% of the time, and other modules rated as difficult 11-13% of the time (details shown in Table
316 1). This provides evidence that the survey is indeed user friendly.

317 Adaptation of the survey questions, language and training of interviewers took about two weeks in both
318 Trifinio and Lushoto. In Lushoto, Tanzania, in two weeks of data collection with 3 interviewers the
319 responses from 150 households were collected, at a total cost of around \$5000, including the purchase of
320 three tablets. The implementation in Trifinio was a little more complex, as the RHoMIS survey was only one
321 of two surveys implemented as part of a larger project, so it is not possible to determine survey costs
322 working only with RHoMIS. It does however illustrate that the tool is flexible enough to be used in
323 conjunction with other research methods.

324

325 *Indicator scores*

326 The median indicator scores in both locations are shown in Table 2, along with the interquartile range. In
327 both sites farm sizes were generally less than one hectare, and average family size was 4 people (3.6 adult
328 male equivalent), although with quite high variability. Livestock ownership was significantly higher in
329 Lushoto, as well as crop diversity and intensification. The reported values of these three variables were all
330 low in Trifinio, indicative of a basic farming system where most households grow only one crop and keep a
331 couple of chickens. Market orientation was significantly different in the two sites, with households in
332 Trifinio purchasing on average about 10% of their food and households in Lushoto purchasing about 30%.
333 Off-farm income was significantly higher in Trifinio than in Lushoto.

334

335 Food availability showed high variability between households in both locations, but median values were
336 within the expected range (2000-4000 kcal per day per person) in Lushoto, but very high in Trifinio (median
337 9000 kcal per day per person). The higher values in Trifinio are likely due to the predominance of maize as
338 the main and often only crop, thereby indicating the limitations of using this indicator which only uses
339 energy as the common denominator. Productivity, measured in Mcal per hectare per year, was similar in both
340 sites, although there was substantially higher variability in Lushoto. Dietary diversity scores in the good
341 season were higher in both locations than in the bad season (as would be expected), and were significantly
342 higher in Tanzania during both seasons. Household food insecurity of access scale (HFIAS) scores indicated
343 moderate levels of food insecurity, with greater variability in Trifinio suggesting more households
344 experiencing severe food insecurity, although overall there was no significant difference in the median
345 HFIAS scores between sites. Progress out of Poverty Index scores were around the lower half of the scale in
346 both locations, indicating that approximately 50% of households could be expected to be below the \$1.25
347 poverty line. Cash value of production is higher in Trifinio than in Lushoto, a result of higher farm gate
348 prices, especially for beans. The gender equity indicator showed median values of 0.5 in Lushoto and 0.6 in
349 Trifinio, which suggests an approximately equal division of responsibility between men and women in the

household over the use of farm produce, although there was higher variability in the Tanzanian site. Greenhouse gas emissions and emission intensity were significantly higher in the Tanzanian site, probably due to the significantly higher livestock ownership, and also higher fertiliser use. Both sites showed high variability in GHG emissions and emission intensities.

Relationships between performance indicators

In both sites, there is a high degree of co-variance between the six main household performance indicators (Table 3), demonstrating that the challenges measured by these indicators are highly interlinked. Many of the typical expected relationships were found in both locations. Higher food availability was correlated with decreased experience of food insecurity, decreased poverty, and improved dietary diversity (the latter in the bad season only though). Dietary diversity in the good and bad seasons were highly correlated. Higher food insecurity scores (i.e. more food insecure households) were correlated with worse dietary diversity in both seasons, and worse poverty status. The correlation coefficients between progress out of poverty and the food security indicators are higher in Trifinio than in Lushoto, implying stronger relationships. This might imply that wealth and off farm income (see also Table 2) is a more important route to obtaining diverse and sufficient food stuffs, where as in Tanzania agricultural production is the more important route. However, it is risky to conclude this on a single survey like this, but it shows how such an integrated, multi-indicator survey tool can generate insights that open targeted avenues for further investigation. Increased gender equity showed negative correlations with food availability, dietary diversity, and progress out of poverty, although it also showed correlation with improved HFIAS score in Trifinio. Increased greenhouse gas emissions were correlated with improved food availability, dietary diversity, and food insecurity (more and stronger correlations in Trifinio). Significant correlation coefficients are mainly in the region 0.15 to 0.35, which implies that while the indicators are co-correlated, they are not measuring the same phenomena.

Farming strategies and their 'Climate smartness'

In Lushoto (Figure 2; Table 4) intensification is associated with higher Food Availability, PPI and cash value of production, and to a smaller extent to higher GHG emissions (Figure 2a). Households who have intensified also have significantly higher market orientation and higher crop diversity (see Supplementary information), so it is important to note that the three strategies are not independent. On large farms, intensification is also linked to significant increases in Productivity and Value of farm produce, while being related to significant decreases in GHG intensity and gender equity. On small farms it is linked to improved HFIAS and dietary diversity scores and is associated with higher off farm income. Increased crop diversity shows very similar relationships with the performance indicators as intensification in Lushoto, except that the effects of increased crop diversity on the important food security indicators HDDs and HFIAs is still more pronounced (Figure 2b). So this indicates that intensification without increasing crop diversity not necessarily leads to the same positive effects on diets and food security as with increased diversification. Increased market orientation on large farms is associated with a strong decrease in gender equity and off

387 farm income and with higher productivity, but shows no significant relationships with the other performance
388 indicators. In small farms in Lushoto increased market orientation is associated with higher values for PPI,
389 but also with slightly lower values for HFIAS and HDDS: the cash generated by selling produce is
390 apparently not being spent on buying diverse food items.

391

392 In Trifinio (Figure 3; Table 4) intensification is related to higher values of PPI and HFIAS on both the small
393 and large farms. On large farms it is also related to increased emissions, value of farm produce and
394 productivity, while on small farms it is related to increased productivity and diet diversity. Gender equity on
395 both farms tends to be lower with increased intensification on both farm types. Off farm income shows an
396 opposite trend between the two farm types: higher intensification on large farms has a strongly negative
397 association with off farm income, while on small farms there is a positive association, although it is not a
398 very strong relation. Crop diversity effects on the performance indicators are less strong compared to
399 intensification (Figure 3b), with farms with less crop diversity performing quite similar in terms of HFIAS,
400 HDDS and PPI as farms with more different crops. The spider diagram 'shape' of higher crop diversity is
401 very similar to the intensification one for large farms (Figure 3a). On small farms crop diversity, similar to
402 the results in Lushoto, had a significantly positive relation with diet diversity, while it is also associated with
403 increased emissions and emission intensities. Increased market orientation (Figure 3c) follows quite similar
404 patterns again as increased intensification, although the negative relationships with off farm income are more
405 marked on both farm types. Similar to Lushoto, increased market orientation is related to significantly lower
406 female decision making (gender equity indicator).

407

408 **Discussion**

409

410 In both study sites the RHoMIS tool met our stated goals of providing rapid, user friendly, and flexible
411 output; both in terms of ease of implementation of the survey by enumerators and by providing efficient data
412 management and analysis. Some of the indicators could be improved upon to give more nuanced
413 interpretations, although there is always tension between speed of survey and detail of results (e.g. Mina et
414 al., 2008; Coates, 2013; De Weerd et al., 2015). When considering food security and nutrition there is a
415 clear trade-off between the level of detail that can be achieved in quantifying intake of different foodstuffs of
416 individual actors, versus the goal of obtaining a sufficiently accurate picture of the village or local eating
417 habits. An example is the use of the household dietary diversity score (e.g. Kennedy et al., 2011). In nutrition
418 oriented research the gold standard is (at the moment) the 24 hour recall collecting detailed information on
419 what several individual members of a household consumed the previous 24 hours (Coates, 2013). However,
420 this data is more time consuming to collect, plus provides only a current snapshot the nutritional situation.
421 Several surveys per year are required to capture seasonal variation and repeat surveys to measure trends have
422 to take place during the same season to avoid confounding effects. Our approach of asking about frequency
423 of consumption (daily/weekly/monthly) in the 'good' and 'bad' seasons may be less accurate, but may obtain a

424 general picture much more quickly, and appeared to function well at the level of detail required for the
425 present study, and we could take the analysis one step further by calculating approximate vitamin input from
426 the food groups). Potential improvements to the mitigation indicators could be inclusion of the IPCC Tier 2
427 methodology, which would allow for better evaluation of the GHG impact of livestock management and land
428 use changes, and an evaluation of the sequestration potential of the farm system could be a useful addition
429 (Lamb et al., 2016). Gender equity could be developed further, taking account of ownership of productive
430 resources and household head status, allowing for more focused analysis on the relationships between food
431 security and gender equity issues (Alkire et al, 2013, Mersha and Laerhoven, 2016). Given the modular
432 design it is relatively straight-forward to expand the RHoMIS tool to take account of other topics, too, such
433 as farmer motivations and attitudes to innovation and risk, or more advanced compound indicators to
434 evaluate different types of sustainable and non-sustainable intensification.

435

436 Overall, the standardized indicator approach allows for comparison between the two sites, which, when
437 applied to more locations, will be useful for gaining a better understanding of the interactions between
438 household food security and trends in agricultural production in different regions of the world (Carletto et al.,
439 2013). Interestingly, the Trifinio site scores high on food availability and productivity (energy based
440 indicators), but scores low on food insecurity of access and household dietary diversity. This matches the
441 observation of ‘hidden hunger’ in Guatemala whereby sufficient calorie intake is not matched by sufficient
442 total nutrient or micro-nutrient intake (Hoddinott et al., 2008). Diets in the study area mainly consist of
443 maize and beans with little else. This observation is also supported by the low crop diversity score. Because
444 improved dietary diversity scores are generally correlated with increased crop diversity, intensification and
445 market orientation, further yield increases in this system, for example in maize, will not necessarily lead to
446 improved nutrition and food security (Harris and Orr, 2014; Frelat et al., 2016). In addition, maize in this
447 system are highly unpredictable, considering the drought conditions which have persisted since 2014 until
448 the time of writing. Our results suggest that interventions should focus on increasing the diversity of crops
449 grown, incorporating drought tolerant, marketable crops, and on empowering women to gain better control
450 over the cash generated by the crops in order to buy more diverse food items. In Lushoto, Tanzania, farms
451 are more diverse in terms of the crops grown and there is more livestock, all leading to (relatively) better
452 scores on diet diversity although the total energy available from food production is far less than in
453 Guatemala. However, the scores of the various food-oriented indicators still represent poor nutrition and
454 moderate experience of food insecurity.

455 If we use PPI, off farm income, total value of farm produce and gender equity as indicative of adaptive
456 capacity, another key pillar of CSA (the only one not directly captured in one of the indicators available),
457 then both sites have fairly similar scores: no significant difference in PPI scores, a small difference in gender
458 equity and the farms in Trifinio generating more cash value for their produce and earning more off farm
459 income. Income from the actual sale of produce shows significant correlation with improved status of all
460 other indicators (see Supplementary Information), and PPI shows correlation with improvements in most

461 indicators (with the exception of greenhouse gas emissions in both cases). However, gender equity in general
462 is negatively associated with increased intensification and market orientation, and households reporting a
463 very high score on female decision making tend to be households where no male is present, either due to
464 death or due to working away. These households have a shortage of labour and therefore tend to score lower
465 on income, productivity and food security, restricting their ability to intensify and produce for the market
466 (e.g. Njuli et al., 2011), thereby resulting in barriers to adoption that are different from those of male headed
467 households (Mersha and Van Laerhoven, 2016).

468

469 Greenhouse gas emissions rise in tandem with most of the improvements to income and food security
470 measured in this study. This presents a central challenge for climate smart interventions which aim to
471 simultaneously mitigate emissions and improve food security. However, the results show how farm
472 intensification can, on larger farms, lower the greenhouse gas intensity of production. Climate smart
473 interventions need to balance the benefits that increased fertiliser use and animal husbandry bring to food
474 security and adaptive capacity against the additional emissions generated. From this perspective,
475 interventions improving the efficiency of the system (such as improving nitrogen use efficiency in manures
476 and improving feed quality to reduce methane output and livestock weight gain) are preferable compared to
477 interventions aiming only to increase the quantity of livestock or fertiliser used. However, when considering
478 such trade-offs, it should be kept in mind that the absolute values of emissions from these systems are still
479 relatively low compared to agricultural systems in the developed world (e.g. Henderson et al., 2016),
480 especially in Trifinio where little livestock is present.

481

482 Closer examination of the farms with the most and least productive resources (land and livestock) in each
483 site showed that the climate smartness of different farm strategies or interventions is strongly influenced by
484 the characteristics of the farm household. For example, the intensification of production using chemical
485 fertilisers on small farms in both sites appeared to be driven by off-farm income. The off farm income in
486 these cases not only directly affects food security positively (e.g. Otsuka and Yamano, 2006; Kristjanson et
487 al., 2011), but is also likely to generate that bit of extra cash that supports investment in intensification of the
488 system, with the knock-on improvements to food security. It seems that on small farms the boost of off-farm
489 income needs to be in place before agricultural intensification (or other strategies) can be promoted
490 successfully (see also Frelat et al., 2016). On large farms higher off farm income is associated with lower
491 intensification, lower crop diversity and lower market orientation. This suggests that for the large farms a
492 choice is made between investing labour in off farm incomes, or investing that the labour into the farm. This
493 may be due to the higher labour required to manage a larger farm, or it may be that a larger farm can more
494 easily produce the minimum requirement for subsistence, and thus the farmers feel less compelled to
495 intensify production if they can also obtain an off-farm wage. It would be useful to find out if there are
496 common thresholds of farm size or livestock ownership and at which household decision making changes.

497

498 **Conclusions**

499

500 The balance of indicators in the current iteration gave an adequate snap-shot of the two sites, and appraised
501 the 'CSA-ness' of farm strategies, and could be used in a post-hoc project evaluation of specific CSA
502 interventions. The applications are not limited to CSA, however, as the RHoMIS tool aims to be a generic
503 indicator framework, and after specific adaptations its potential list of application possibilities is large:
504 integrated natural resource management, integrated nutrient management, conservation agriculture, organic
505 agriculture, integrated pest management, agroforestry, integrated soil fertility management and many others
506 (e.g. Lambrecht et al., 2016), while it can also be used for the construction of farm types to aid the targeting
507 of interventions across farming systems (e.g. Sakane et al., 2013; Giller et al., 2011) or generate the right
508 inputs to be used in modelling exercises for ex-ante impact assessments (e.g. Van Wijk et al., 2014b; Herrero
509 et al., 2014). Providing a standardised baseline provides multiple benefits but indicator standardization is a
510 line of research that has been largely ignored in the current literature (e.g. De Weerd et al., 2015; Carletto et
511 al., 2015).

512

513 Our results show that the climate smartness of different farm strategies or interventions not only depends on
514 the strategy or intervention itself, but is also determined by an interaction between the characteristics of the
515 farm household and the farm strategy (see also Coe, Sinclair, & Barrios, 2014). This finding stresses the
516 importance of more fine-grained farm household based analyses to assess for which groups certain strategies
517 or interventions are 'smart', and for which households they are less 'smart' (or even 'stupid'). Avoiding
518 strategies that are inappropriate from the outset may be one of the most important uses of the RHoMIS tool,
519 while identifying truly smart strategies will require not only ex ante analysis, but also experimentation and
520 iterative evaluation.

521 **Acknowledgements**

522

523 We thank all the people involved in collecting the field data that formed the basis for the analyses and
524 especially the farmers for sharing their valuable information. We thank the two anonymous referees and
525 the editors of Agricultural Systems for their useful comments that helped improve this manuscript.

526 This work is a joint output of the CGIAR Research Programs on Livestock and Fish and CCAFS.

527

528 **References**

529

530 Alkire, S., Malapit, H., Meinzen-Dick, R., Peterman, A., Quisumbing, A., Seymour, G., Vaz, A., 2013.
531 *Instructional Guide on the Women ' s Empowerment in Agriculture Index*, IFPIR, Washington D.C. USA.
532 82pp. Available at: https://www.ifpri.org/sites/default/files/Basic Page/weai_instructionalguide_1.pdf.

533

534 Campbell, B., Mann, W., Meléndez-Ortiz, R., Streck, C., Tennigkeit, T., 2011. Agriculture and Climate
535 Change: A Scoping Report. Washington, DC: Meridian Institute.

536

537 Campbell, B.M., Thornton, P., Zougmore, R., van Asten, .P, Lipper, L., 2014. Sustainable intensification:
538 What is its role in climate smart agriculture? Current Opinion in Environmental Sustainability
539 8, 39–43.

540

541 Carletto, C., Jolliffe, D., Banerjee, R., 2015. From Tragedy to Renaissance: Improving Agricultural Data for
542 Better Policies. The Journal of Development Studies 51(2), 133–148.

543

544 Carletto, C., Zezza, A., Banerjee, R., 2013. Towards better measurement of household food security:
545 Harmonizing indicators and the role of household surveys. Global Food Security, 2(1), 30–40.

546

547 Coates, J., Frongillo, E.A., Rogers, B.L., Webb, P., Wilde, P.E., Houser, R., 2006. Commonalities in the
548 experience of household food insecurity across cultures: what are measures missing? Journal of Nutrition
549 136(5), 1438S–1448S.

550

551 Coates, J., Swindale, A., Bilinsky, P., 2007. Household Food Insecurity Access Scale (HFIAS) for
552 measurement of food access: indicator guide, Washington, DC.

553

554 Coates, J., 2013. Build it back better: Deconstructing food security for improved measurement and action.
555 Global Food Security 2(3), 188-194.

556

557 Coe, R., Sinclair, F., Barrios, E., 2014. Scaling up agroforestry requires research “in” rather than “for”
558 development. *Current Opinion in Environmental Sustainability* 6(1), 73–77.
559

560 Delaney, A., Chesterman, S., Crane, T.A., Tamás, P.A., Ericksen, P., 2014. A systematic review of local
561 vulnerability to climate change: In search of transparency, coherence and compatability. CCAFS Working
562 Paper no. 97. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).
563 Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org.
564

565 Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Courbois, C., 1999. Livestock to 2020. The next
566 revolution. . Food, agriculture, and the environment discussion paper 28. Washington, USA, IFPRI, pp 74.
567

568 Desiere, S., Vellema, W., D’Haese, M., 2015. A validity assessment of the Progress out of Poverty Index
569 (PPI)TM. *Evaluation and Program Planning*, 49, 10–18.
570

571 De Weerd, J., Beegle, K., Friedman, J., Gibson, J., 2015. The Challenge of Measuring Hunger through
572 Survey. LICOS Discussion Paper Series, Discussion Paper 365/2015, Leuven, pp36. Available at
573 https://lirias.kuleuven.be/bitstream/123456789/488089/1/DP+365_2015.pdf.
574

575 Ellis, F., 2009. Strategic dimensions of rural poverty reduction in sub-Saharan Africa. In B. Harriss-White &
576 J. Heyer, eds. *The Comparative Political Economy of Development: Africa and South Asia*. Routledge
577 Studies in Development Economics. Taylor & Francis. Available at:
578 <https://books.google.co.uk/books?id=rXKMAgAAQBAJ>.
579

580 FAO, 2013. Climate smart agriculture. Sourcebook. Rome, Italy, FAO: p. 570.
581

582 Förch, W., Kristjanson, P., Cramer, L., Barahona, C., Thornton, P.K., 2014. Back to baselines: measuring
583 change and sharing data. *Agriculture & Food Security* 3:13.
584

585 Foster, A. D., Rosenzweig, M. R., 2008. Economic development and the decline of agricultural employment.
586 In T. Paul Schultz and John Strauss (Eds.), *Handbook of Development Economics*, pp. 3051–3083. Oxford:
587 North Holland.
588

589 Frelat, R., Lopez-Ridaura, S., Giller, K.E., Herrero, M., Douchamps, S., Djurfeldt, A., Erenstein, O.,
590 Henderson, B., Kassie, M., Paul, B., Rigolot, C., Ritzema, R., Rodriguez, D., van Asten, P., van Wijk, M.T.,
591 2016. Drivers of household food availability in sub-Saharan Africa based on big data from small farms.
592 *PNAS* 113 (2), 458–463.
593

594 Giller, K.E., Tittonell, P., Rufino, M.C., van Wijk, M.T., Zingore, S., Mapfumo, P., Adjei-Nsiah, S., Herrero,
 595 M., Chikowo, R., Corbeels, M., Rowe, E.C., Baijukya, F., Mwijage, A., Smith, J., Yeboah, E., van der Burg,
 596 W.J., Sanogo, O.M., Misikom, M., de Ridder, N., Karanja, S., Kaizzi, C., K'ungu, J., Mwale, M., Nwaga,
 597 D., Pacini, C., Vanlauwe, B., 2011. Communicating complexity: Integrated assessment of trade-offs
 598 concerning soil fertility management within African farming systems to support innovation and
 599 development. *Agricultural Systems* 104, 191-203.
 600
 601 Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S.,
 602 Thomas, S.M., Toulmin, C., 2010. Food Security: The Challenge of Feeding 9 Billion People. *Science*
 603 327(5967): 812-818.
 604
 605 Grameen Foundation, 2015. Progress out of Poverty Index. Available at:
 606 <http://www.progressoutofpoverty.org/> [Accessed August 3, 2015].
 607
 608 Harris, D., Orr, A., 2014. Is rainfed agriculture really a pathway from poverty? *Agricultural Systems*, 123,
 609 84–96.
 610
 611 Hartung, C., Anokwa, Y., Brunette, W., Lerer, A., Tseng, C., Borriello, G., 2010. Open Data Kit: Tools to
 612 Build Information Services for Developing Regions. *Proceedings of the International Conference on*
 613 *Information and Communication Technologies and Development*, pp.1–11. Available at:
 614 papers2://publication/uuid/ACE2FDB0-CD33-475F-A750-0331358C1976.
 615
 616 Henderson, B., Godde, C., Medina-Hidalgo, D., van Wijk, M., Silvestri, S., Douchamps, S., Stephenson, E.,
 617 Power, B., Rigolot, C., Herrero, M., 2016. Closing system-wide yield gaps to increase food supply and
 618 mitigate GHGs among mixed crop livestock smallholders in Sub-Saharan Africa. *Agricultural Systems* 143,
 619 106-113.
 620
 621 Herrero, M., Thornton, P. K., Bernués, A., Baltenweck, I., Vervoort, J., van de Steeg, J., et al., 2014.
 622 Exploring future changes in smallholder farming systems by linking socio-economic scenarios with regional
 623 and household models. *Global Environmental Change*, 24(1), 165-182.
 624
 625 Hoddinott, J., Maluccio, J.A., Behrman, J.R., Flores, R., Martorell, R., 2008. Effect of a nutrition
 626 intervention during early childhood on economic productivity in Guatemalan adults. *The Lancet*, 371(9610),
 627 411–416.
 628
 629 IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Available at: [http://www.ipcc-](http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm)
 630 [nggip.iges.or.jp/public/2006gl/index.htm](http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm).

631

632 Johnson, K.B., Diego-Rosell, P., 2015. Assessing the cognitive validity of the Women's Empowerment in
633 Agriculture Index instrument in the Haiti Multi-Sectoral Baseline Survey. Survey Practice; Vol 8, No 3.
634 Available at: <http://surveypractice.org/index.php/SurveyPractice/article/view/288>.

635

636 Kennedy, G., Ballard, T., Dop, M., 2011. Guidelines for measuring household and individual dietary
637 diversity, FAO, Rome, 53 pp.

638

639 Klapwijk L., van Wijk, M.T., van Asten, P., Thornton, P.K., Giller, K.E., 2014. Trade-off Analysis in
640 (Tropical) Agricultural Systems. COSUST 6, 110 – 115.

641

642 Kristjanson P., Mango, N., Krishna, A., Radeny, M., Johnson, N. 2010. Understanding poverty dynamics in
643 Kenya. Journal of International Development 22(7), 978–996.

644

645 Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Förch,
646 W., Thornton, P.K., Coe, R., 2012. Are food insecure smallholder households making changes in their
647 farming practices? Evidence from East Africa. Food Security 4(3), 381–397.

648

649 Lamb, A., Green, R., Bateman, I., Broadmeadow, M., Bruce, T., Burney, J., Carey, P., Chadwick, D., Crane,
650 E., Field, R., Goulding, K., Griffiths, H., Hastings, A., Kasoar, T., Kindred, D., Phalan, B., Pickett, J., Smith,
651 P., Wall, W., zu Ermgassen, E.K.H.J., Balmford, A., 2016. The potential for land sparing to offset
652 greenhouse gas emissions from agriculture. Nature Climate Change, advance online publication. Available
653 at: <http://dx.doi.org/10.1038/nclimate2910>.

654

655 Lambrecht, I., Vanlauwe, B., Maertens, M., 2016. Integrated soil fertility management: from concept to
656 practice in Eastern DR. International Journal of Agricultural Sustainability 14, 100-118.

657

658 Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A.,
659 Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck,
660 A., Neufeldt, H., Remington, T., Thi Sen, P., Sessa, R., Shula, R., Tibu, A., Torquebiau, E.F., 2014. Climate-
661 smart agriculture for food security. Nature Climate Change 4(12), 1068–1072.

662

663 Livingston, G., Schonberger, S., Delaney, S., 2011. Sub-Saharan Africa: The state of smallholders in
664 agriculture. In IFAD Conference on New Directions for Smallholder Agriculture. Rome. Available at:
665 <http://www.ifad.org/events/agriculture/doc/papers/livingston.pdf>.

666

667 Lyamchai, C., Yanda, P., Sayula, G., Kristjanson, P., 2011. Summary of baseline household survey results :
668 Lushoto , Tanzania. pp34. Available at: <https://cgspace.cgiar.org/rest/bitstreams/16259/retrieve>.
669

670 Mersha, A.A., Van Laerhoven, F., 2016. A gender approach to understanding the differentiated impact of
671 barriers to adaptation : responses to climate change in rural. Regional Environmental Change, in press.
672

673 Mina, K., Fritschi, L., Knuiman, M., 2008. Do aggregates of multiple questions better capture overall fish
674 consumption than summary questions? Public Health and Nutrition 11(2), 196–202.
675

676 Morchain, D., Prati, G., Kelsey, F., Ravon, L., 2015. What if gender became an essential, standard element
677 of Vulnerability Assessments? Gender & Development 23(3), 481–496.
678

679 Neufeldt, H., Jahn, M., Campbell, B.M., Beddington, J.R., DeClerck, F., Pinto, A.D., Gullledge, J., et al.,
680 2013. Beyond climate-smart agriculture: toward safe operating spaces for global food systems Agric Food
681 Security 2 (12), 6.
682

683 Njuki, J., Poole, J., Johnson, N., Baltenweck, I., Pali, P., Lokman, Z., Mburu, S., 2011. Gender, Livestock
684 and Livelihood Indicators, ILRI, Nairobi. pp 40.
685

686 Otsuka, K., Yamano, T., 2006. Introduction to the special issue on the role of nonfarm income in poverty
687 reduction: Evidence from Asia and East Africa. Agric Econ 35(S3), 393–397.
688

689 Randall, S., Coast, E., 2015. Poverty in African Households : the Limits of Survey and Census
690 Representations. The Journal of Development Studies, 51(2), 162–177.

691 Ritzema, R.S., Frelat, R., Douchamps, S., Silvestri, S., Rufino, M., Herrero, M., Giller, K.E., Lopez-
692 Ridaura, S., Teufel, N., Paul, B., van Wijk, M.T., 2016. A simple food availability analysis across
693 smallholder farming systems from East and West Africa: Is production intensification likely to make farm
694 households food-adequate? Submitted to Food Security.
695

696 Sakané, N., Becker, M., Langensiepen, M., van Wijk, M.T., 2013. Typology of smallholder production
697 systems in small East-African wetlands. Wetlands 33, 101–116.
698

699 Sandefur, J., Glassman, A., 2015. The Political Economy of Bad Data: Evidence from African Survey and
700 Administrative Statistics. The Journal of Development Studies 51(2), 116–132.

701

702 Scherr, S.J., Shames, S., Friedman, R., 2012. From climate-smart agriculture to climate-smart landscapes.

703 Agric. Food Secur. 1, 12.

704

705 Smyth, I., Sweetman, C., 2015. Introduction: Gender and Resilience. Gender & Development 23(3), 405–

706 414.

707

708 Steenwerth, K.L., Hodson, A.K., Bloom, A.J., Carter, M.R., Cattaneo, A., et al., 2014. Climate-smart

709 agriculture global research agenda: scientific basis for action. Agric. Food Secur. 3(1), 1–39.

710

711 Swindale, A. Bilinsky, P., 2006. Household Dietary Diversity Score (HDDS) for measurement of household

712 food access: Indicator guide, Washington, DC. Available at: ftp://190.5.101.50/DISCO 2/SRV-SQL/Nueva

713 carpeta/doc lili bakup6654444/LILY/Monitoreo y Evaluacion/FANTA/fanta HDDS_Mar05

714 DIVERSIFICACION.doc.

715

716 Tiffen, M., 2003. Transition in Sub-Saharan Africa: Agriculture, Urbanization and Income Growth. World

717 Development 31(8), 1343–1366.

718

719 Van Etten, J., 2011. Crowdsourcing Crop Improvement in Sub-Saharan Africa: A Proposal for a Scalable

720 and Inclusive Approach to Food Security. IDS Bulletin 42(4), 102–110.

721

722 Van Wijk, M.T., Ritzema, R., Valbuena, D., Douchamps, S., Frelat, R., 2014a. A rapid, quantitative

723 assessment of household level food security: description of the data collection tool and the analysis.

724 <https://cgspace.cgiar.org/handle/10568/56694>.

725

726 Van Wijk, M.T., Rufino, M.C., Enahoro, D., Parsons, D., Silvestri, S., Valdivia, R.O., Herrero, M., 2014b.

727 Farm household modelling and its role in designing climate-resilient agricultural systems. Global Food

728 Security 3, 77-84.

729

730 Van Wijk, M.T., 2014. From global economic modelling to household level analyses of food security and

731 sustainability: How big is the gap and can we bridge it? Food Policy 49, 378–388.

732

733 Welch, R.M., Graham, R.D., 1999. A new paradigm for world agriculture: meeting human needs:

734 Productive, sustainable, nutritious. Field Crops Research 60(1–2), 1–10.

735

736 World Bank, 2008. Agriculture for Development, Available at: [http://www.oecd-](http://www.oecd-ilibrary.org/development/agriculture-and-development_9789264013353-en)

737 [ilibrary.org/development/agriculture-and-development_9789264013353-en](http://www.oecd-ilibrary.org/development/agriculture-and-development_9789264013353-en).

738 **Figure Captions**

739

740 Figure 1. Schematic representation of the indicators gathered from the household surveys, and the
741 analytical framework into which they are placed.

742

743 Figure 2. Farm performance scores for large and small farm types (LF and SF) , practising high and
744 low farm intensification (HI and LI), crop diversification (HD and LD) and market orientation (HM
745 and LM) for Lushoto, Tanzania. Abbreviations: FA is Food Availability, HFIAS is the Household
746 Food Insecurity Access Scale, HDDS is the Household Diet Diversity Score, PPI is Progress out of
747 Poverty Index.

748

749 Figure 3. Farm performance scores for large and small farm types (LF and SF), practising high and
750 low farm intensification (HI and LI), crop diversification (HD and LD) and market orientation (HM
751 and LM) for Trifinio, Central America. Abbreviations: FA is Food Availability, HFIAS is the
752 Household Food Insecurity Access Scale, HDDS is the Household Diet Diversity Score, PPI is
753 Progress out of Poverty Index.

754

755

756 Table 1: Time taken to gather data for each indicator, and the ease of that data gathering, as rated by the interviewers during the Lushoto survey,
 757 n=151.
 758

Module	Mean time needed (minutes per household)	Proportion of times module perceived as easy (%)	Proportion of times module perceived as medium (%)	Proportion of times module perceived as difficult (%)
FA	15 –35	56	31	13
HFIAS	5	54	34	12
Dietary Diversity	10	54	34	12
PPI	3-5	61	34	5
Gender Equity	5	61	28	11
GHG Emissions	5	57	32	11

759
 760

761 Table 2: Results of Indicators and drivers, with units and the possible scoring ranges shown in parentheses. Significant differences between the sites
762 were measured using the Wilcoxon rank-sum test and indicated by the following symbols: † p<0.1; * p<0.05; ** p<0.01, *** p<0.001.

763

Indicator	Trifinio (n=285)		Lushoto (n=150)	
(unit) (possible range)	Median	IQR	Median	IQR
Farm size (ha)	0.7	0.9	0.8	0.8
Livestock ownership (tlu) ***	0.2	0.3	1.2	2.2
Family Size (adult male equivalent)	3.6	2.5	3.6	2.0
Crop Diversity (number of crops grown) ***	1.0	1.0	3.0	2.0
Intensification (kg nitrogenous fertiliser per hectare) **	5.0	5.0	10.0	47.5
Market Orientation (0-1) ***	0.1	0.3	0.3	0.5
Food Availability (kcal per mae per day) ***	9922.7	20139.8	3174.3	5418.4
Farm Productivity (Mcal per hectare per year)	5104.0	5878.8	5007.8	8146.5
Household Food Insecurity Access Scale (HFIAS) (0-27)	8.0	9.0	9.0	6.0
Dietary Diversity (good season) (HDDS) (0-12) ***	7.0	4.0	9.0	3.0
Dietary Diversity (bad season) (HDDS) (0-12) ***	5.0	4.0	6.0	4.0
Progress out of Poverty Index (PPI) (0-100)	40.0	32.0	42.0	20.0
Off Farm Income (USD per year) ***	489.1	1726.6	0.0	261.5
Value of Farm Produce (USD per year)***	550.7	846.1	340.8	634.7
Gender Equity (0-1) †	0.6	0.3	0.5	0.5
GHG emissions (kgCO ₂ -eq per household per year) ***	498.9	966.0	2761.1	5560.1
GHG intensity (kgCO ₂ -eq per kcal) ***	0.1	0.2	0.5	1.6

764

765

766 Table 3: Correlation table between the six main household performance indicators in Trifinio and Lushoto, using Spearman’s Rho correlation test. The
 767 correlation co-efficient and significance values refer intra-site comaprsons only, there are no correlations between the two sites presented in this table.
 768 Abbreviations: FA is Food Availability, HFIAS is the Household Food Insecurity Access Scale, HDDS is the Household Diet Diversity Score, PPI is
 769 Progress out of Poverty Index, GHGs is Greenhouse Gas emissions. Significance levels are denoted by: † p<0.1; * p<0.05; ** p<0.01, *** p<0.001.
 770

		Lushoto (n=150)						
Trifinio (n=285)	Variable name	FA	HFIAS	HDDS (good)	HDDS (bad)	PPI	Gender Equity	GHGs
	FA		-0.24**	0.11	0.21*	0.34***	-0.19*	0.27**
	HFIAS	-0.19**		-0.18*	-0.31***	-0.31***	-0.02	-0.12
	HDDS (good)	0.26***	-0.23***		0.51***	0.11	-0.08	0.20*
	HDDS (bad)	0.22***	-0.35***	0.55***		0.18*	-0.01	0.12
	PPI	0.23***	-0.51***	0.34***	0.35***		0.02	-0.04
	Gender Equity	-0.05	0.10 [†]	-0.03	-0.15*	-0.15*		-0.21*
	GHGs	0.35***	-0.33***	0.28***	0.26***	0.39***	-0.17**	

771
 772

773 Table 4. The significance of differences in performance indicators for households who do and do not score highly on farm strategies, in Lushoto and in
 774 Trifinio. All values refer to Figures 2 and 3. Abbreviations: FA is Food Availability, HFIAS is the Household Food Insecurity Access Scale, HDDS is
 775 the Household Diet Diversity Score, PPI is Progress out of Poverty Index, GHGs is Greenhouse Gas emissions. Significance levels are denoted by: ns
 776 not significant, † p<0.1; * p<0.05; ** p<0.01, *** p<0.001.

777

778

779

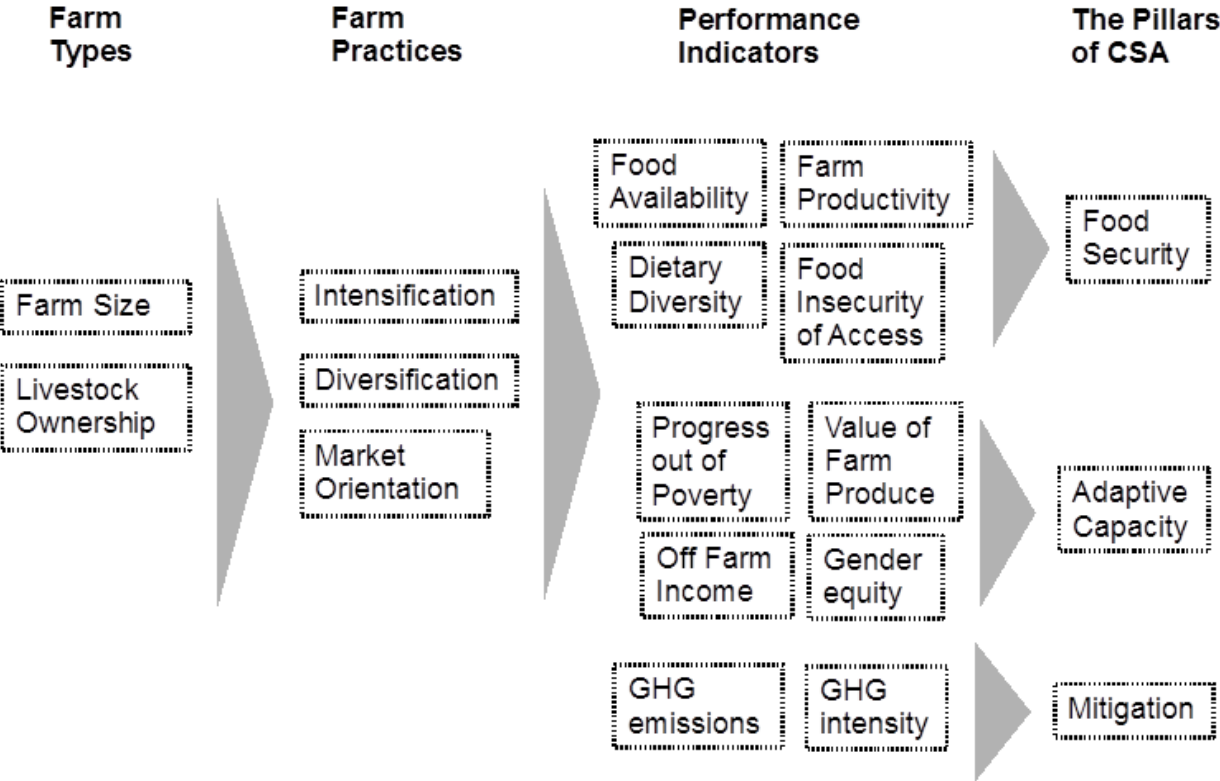
Lushoto, Tanzania	Farm Type	Practice	FA	Productivity	HFIAS	HDDS	PPI	Off Farm Income	Produce Value	Gender equity	GHG emission	GHG intensity
	Large	Intensification	ns	†	ns	ns	*	†	ns	ns	†	ns
	Small	Intensification	†	†	**	**	***	**	*	ns	**	ns
	Large	Diversity	†	†	ns	*	ns	ns	ns	ns	†	ns
	Small	Diversity	ns	ns	ns	ns	ns	ns	ns	ns	ns	*
	Large	Market	ns	†	ns	ns	ns	ns	ns	*	ns	†
	Small	Market	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Trifinio	Farm Type	Practice	FA	Productivity	HFIAS	HDDS	PPI	Off Farm Income	Farm Produce Value	Gender equity	GHG emission	GHG intensity
	Large	Intensification	ns	ns	*	*	*	†	***	ns	*	ns
	Small	Intensification	ns	ns	†	ns	ns	ns	*	ns	ns	ns
	Large	Diversity	ns	*	†	ns	ns	ns	**	ns	***	ns
	Small	Diversity	ns	ns	ns	**	ns	ns	*	ns	**	*
	Large	Market	ns	†	†	**	ns	ns	**	ns	†	ns
	Small	Market	ns	**	ns	*	ns	ns	***	ns	***	ns

780 Figure 1.

781

782

783

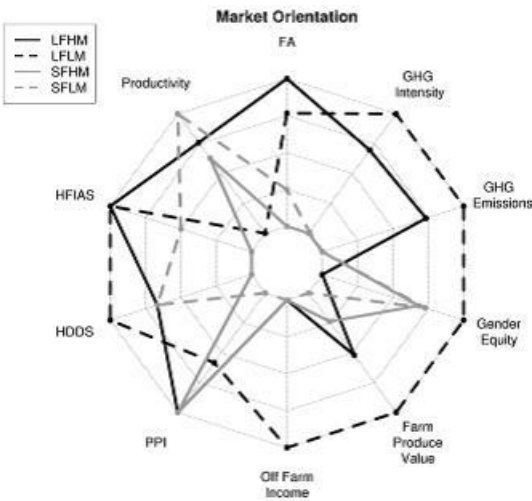
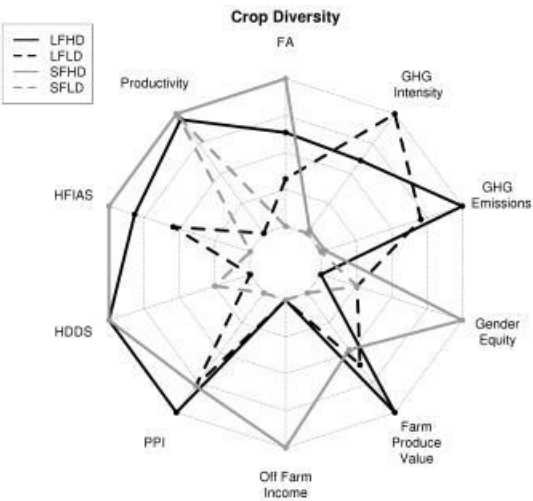
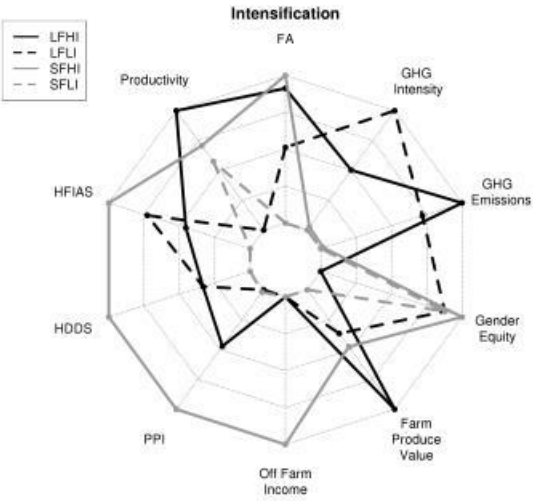


784

785

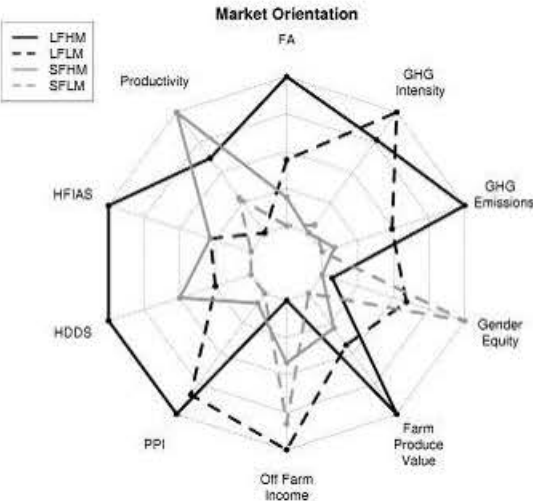
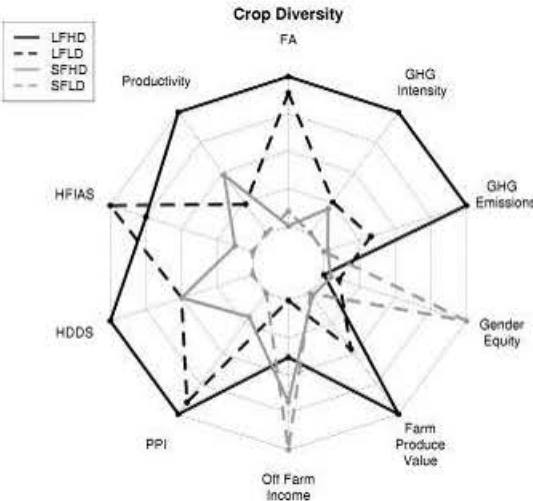
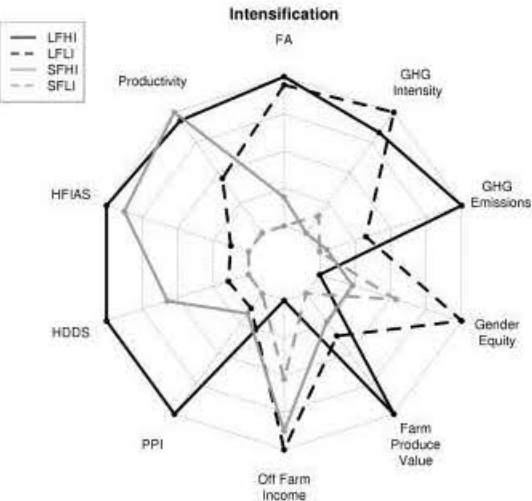
786
787
788
789

Figure 2.



790
791

792 Figure 3.
793
794
795



796

Supplementary material for on-line publication only

[Click here to download Supplementary material for on-line publication only: Supplementary material Hammond etal_RHoMIS_Ta](#)

Supplementary material for on-line publication only

[Click here to download Supplementary material for on-line publication only: Supplementary material Hammond etal_II.docx](#)